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Intelligent Observation Strategies for Geosynchronous Remote Sensing for Natural Hazards

Background Image Source: Contaminated Rio Doce Water Flows into the Atlantic taken on 30 Nov. 2015 by Landsat 8. NASA Earth Observatory image by J. Stevens, SSC-Jacobs. Website: www.earthobservatory.nasa.gov

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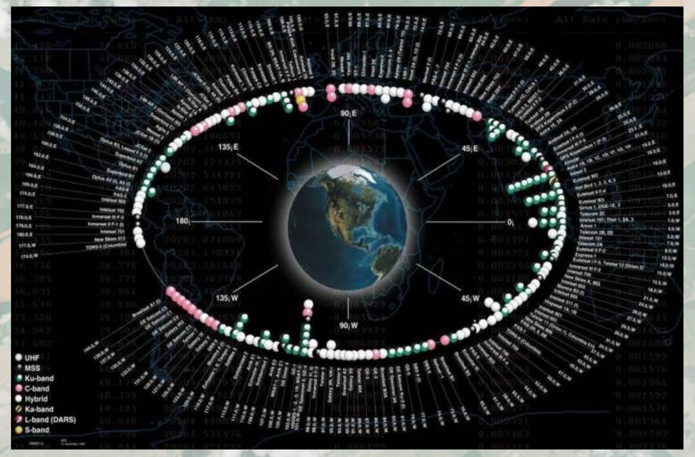
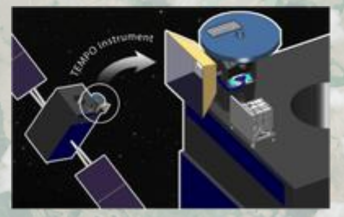
Abstract

Geosynchronous satellites (orbiting in the same rotation period as the Earth) offer a unique perspective for monitoring environmental factors, and for those in the geostationary orbit (circular, equatorial orbits 35.7 km above the surface) 24 hour monitoring is possible. The NRC 2007 decadal survey for NASA Earth science proposed the GEO-CAPE mission to address coastal and air pollution events in geostationary orbit, complementing similar initiatives by the South Koreans in Asia and by ESA in Europe, effectively covering the northern hemisphere. Commercial communication satellites are envisioned to provide a platform for instruments capable of sensing the GEO-CAPE measurements. The Tropospheric Emissions: Monitoring of Pollution (TEMPO) will measure atmospheric pollution covering most of North America hourly at high spatial resolution from geostationary orbit. This NASA Earth Venture instrument will take advantage of a GEO host spacecraft to improve emission inventories, monitor population exposure, and enable effective emission-control strategies for modest mission costs.

This poster addresses the results of a NASA study to explore observation strategies to fully exploit both this unique observing viewpoint and new technologies enabling the rapid acquisition and delivery of environmental data products important to understanding natural hazards and supporting the disasters management life cycle.



Satellites in Geostationary Orbit (www.dreamer-cs.com)



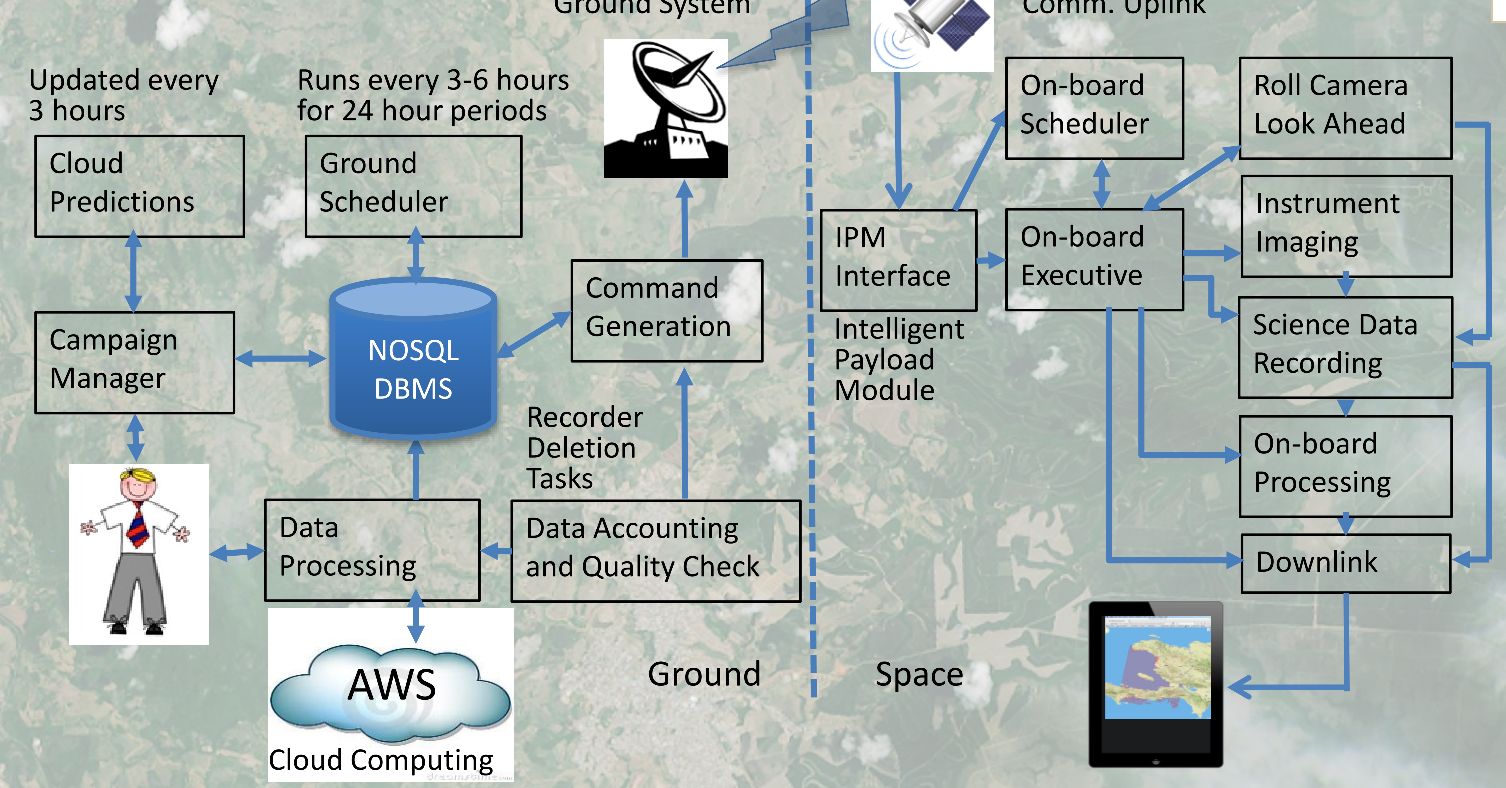
TEMPO on geo-platform http://science.nasa.gov/missions/tempo/

Study Objectives

The goal of the GEO-CAPE oceans observation optimization feasibility study was to research options for an overall observing strategy to maximize the ocean science return. The study identified key scientific benefits such as improved time and quality of observations, and compared costs and benefits of potential strategies. Specifically:

- Examine/develop needs analysis driving ocean instrument operations concepts
- Determine ways to optimize observations with respect to cloud avoidance
- Describe the high-level cost/benefit tradeoff for candidate observation strategies

Scheduling Flow

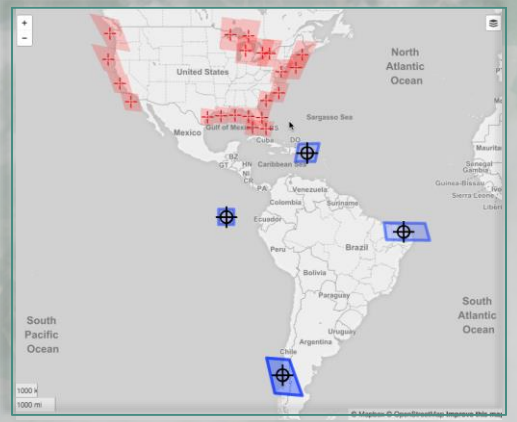


Instrument Scheduling Environment Assumptions

Filter Radiometer (FR) and Coastal Ocean Ecosystem Dynamics Imager (COEDI) were two candidate instrument concepts for the study.

	FR	COEDI
Resolution	375m	375m
Scene Size	512 x 512km	768 x 535.5km
Scene Storage	197.5 MB	304.15 MB
High 30min Repeat	11 scenes	8 scenes
Threshold 1hr	22 scenes	17 scenes
CONUS Coverage	18 scenes	15 scenes
Data Rate	1.25 MB/s	1.46 MB/s
Daily Storage	65.7 GB	102.2 GB
Monthly Downlink	1.97 TB	3.1 TB

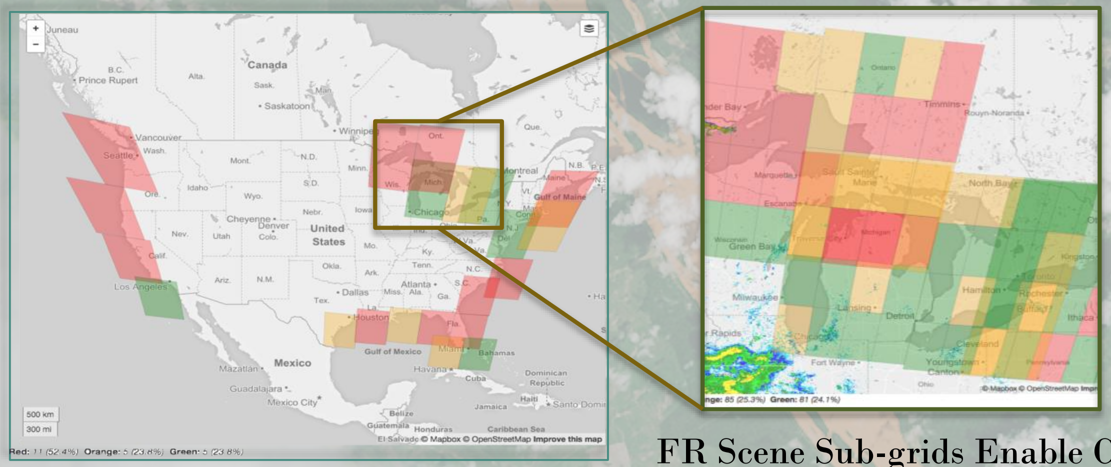
Key Instrument Scheduling Operations Factors



FR Scene Layout:

- Hosted Instrument @95W
- Operate during daylight – 16 hours/day
- Survey Mode (red)
- 60 min repeat frequency (baseline 30 min)
- Targeted events (blue)
- Science team sets cloud thresholds and priorities

Cloud Forecast Scheduling Concepts



Example FR Survey Scene **Schedule with Cloud Thresholds** generated on the ground

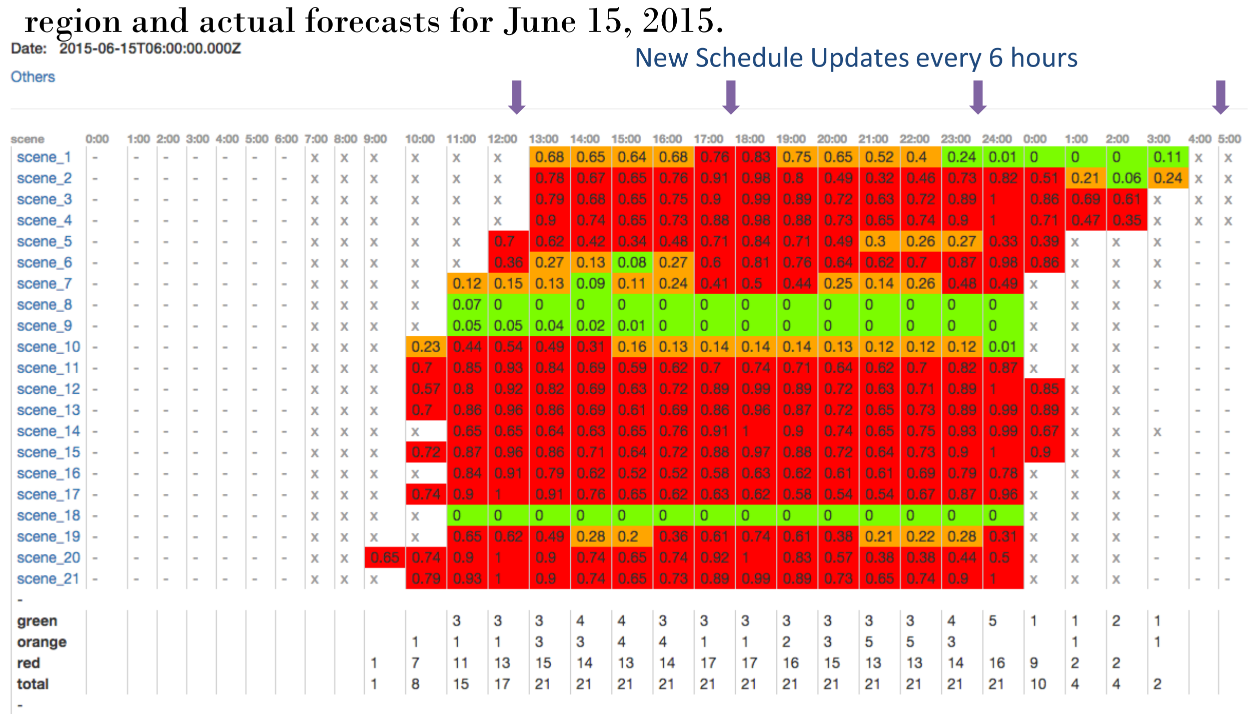
- Red scenes fail cloud threshold
- Green scenes pass – scheduled
- Orange scenes are marginal and are scheduled for more evaluation onboard

Daily schedule includes Green and Orange scenes uplinked to the instrument

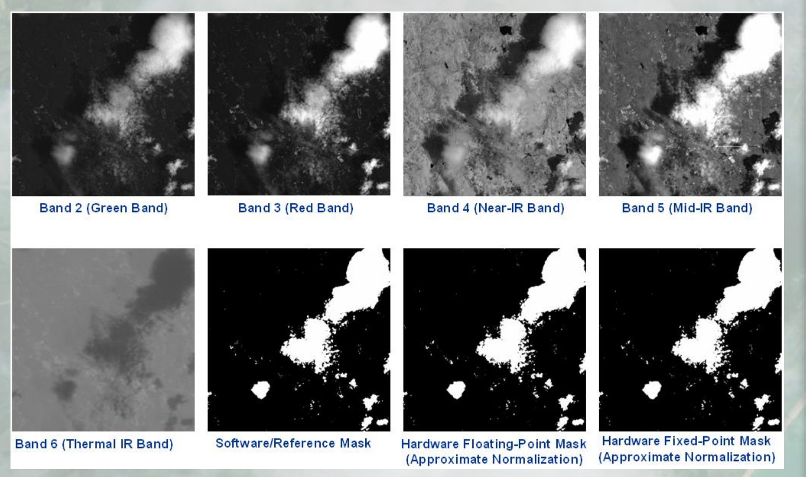
FR Scene Sub-grids Enable Cloud Forecast Optimization for **Onboard Cloud Detection**

- Forecast is obtained at the center of the sub-area of interest and is averaged across scene to generate the scene forecast; land masks can also be used
- Orange marginal scenes are acquired, and onboard cloud detection is employed to determine if cloud threshold is met; if so, observation is downlinked; if not delete to reduce data handling costs

Ground FR Forecast Schedule Example based on cloud threshold criteria per region and actual forecasts for June 15, 2015.



GOES-E cloud analysis shows that the time-of-day for maximum cloud-free condition varies considerably from location to location, supporting the need for geostationary sensor capabilities to image any area at any time of the day to maximize spatial coverage of cloud-free pixels (analysis by Feng, Hu, and Barnes, GEO-CAPE ocean science study team, 2015 ref 1).



Visit GEO-CAPE Observation Operations Simulator

www.geocape.herokuapp.com

Band #	Central W (nm)	BW (nm)	Spatial Res (m)
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	783	20	20
8	842	115	10
8b	865	20	20
9	945	20	60
10	1380	30	60
11	1610	90	20
12	2190	180	20

Key Findings

Hosted payload operations concepts are still evolving. While offering 24/7 monitoring at high resolution, data handling may be a cost driver to mitigate with onboard processing. GSFC's GEO-CAPE Observation Operations Simulator demonstrated the feasibility and benefits for several intelligent observation strategies:

- Daily (or every 6 hour) forecast scheduling; cloud threshold settings and forecast constraints; marginal scene handling
- Onboard processing of cloud detection to only downlink observations that pass cloud thresholds (thus reduce data handling costs)
- Cost effective onboard processing available with 2015 technology

The emerging Internet of Things (IoT) technology provides an opportunity to evolve payload data products to be readily accessible by a user's smart phone or other smart appliance.

References

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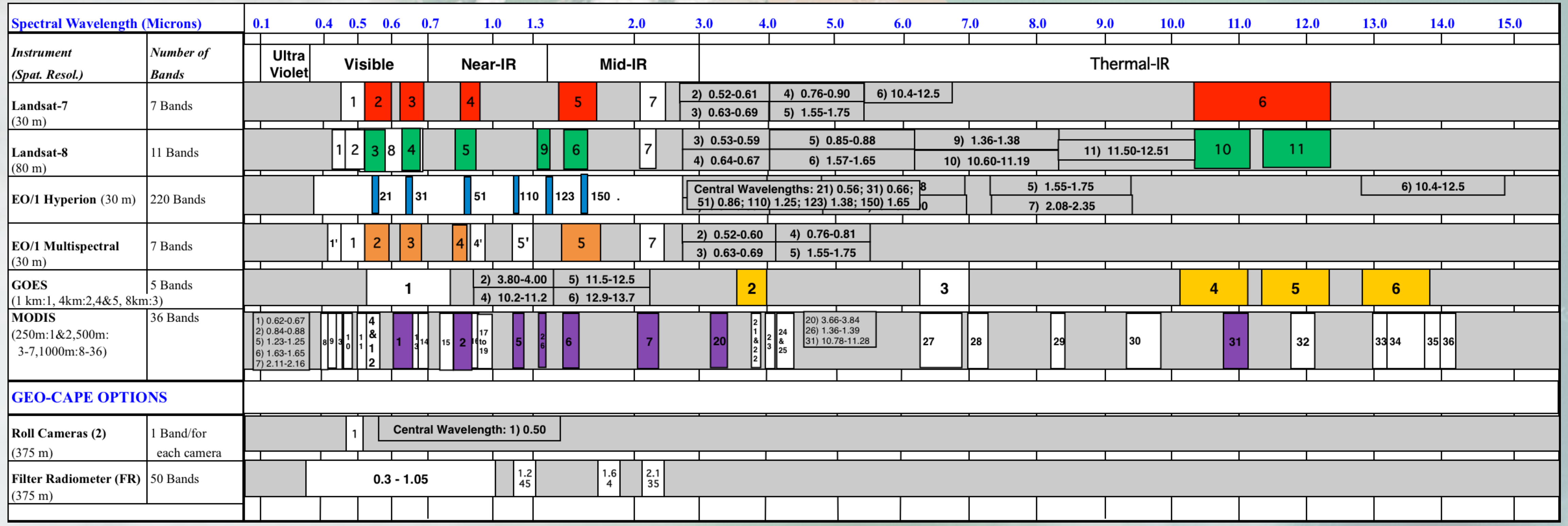
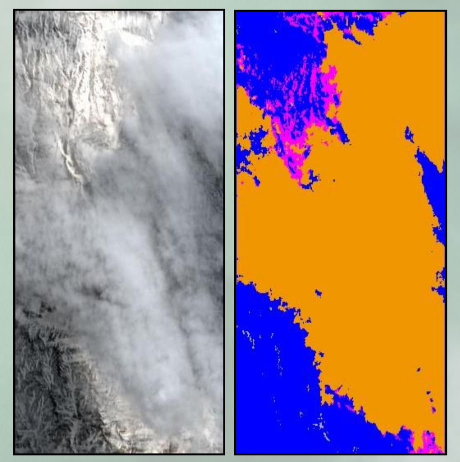
Onboard Cloud Detection Algorithms



Spectral Bands Used in Cloud Detection Algorithms

- Landsat-7 bands: 2, 3, 4, 5 and 6 (Thermal IR) for 30m resolution cloud detection
- GOES bands: 2, 4, 5, 6 for 4km resolution
- EO-1/Hyperion bands: 21, 31, 51, 110, 123, 150, also 30m
- Thermal bands distinguish clouds from ice
- SWIR band 1375nm (used by EO-1 / Landsat-8 / Sentinel 2) is the most critical to detect high cirrus clouds that contaminate scenes, especially in coastal areas



EO-1 Onboard Cloud Detection

The Hyperion image is on the left. The resulting product masks clouds (orange) and identifies non-cloudy (blue) and ice covered surface (pink), and was processed using the EO-1 onboard cloud detection algorithm.

- Hyperion Scene size: 361.6k scanline length (pixels)*12 bands
- Time to process cloud detection code: 0.6 s (0.172 s with level 1 compiler optimization
- Scaling the instrument scene size to the FR dimensions would require ~3 s to process (with no optimization), compared to the 157 s required to acquire the scene